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Simplified FWHA Noise Prediction Method

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ABSTRACT

This report describes the development and application of a simple highway noise prediction method based on the U.S. FHWA highway noise prediction model. The simplification has been achieved mainly by streamlining the actual FHWA model using the assumption that traffic flow speeds of various vehicle classes are correlated and similar in magnitude.

The objective was to make the analytically and acoustically useful but operationally somewhat complex FHWA model more accessible to non-specialists such as environmental planners and highway engineers.

The application of the new method is described as a step-by-step procedure, illustrated with examples, for both simple and more complex situations. Also, the usual mathematical calculations can be avoided by using nomographs, which should further simplify use of the method.

Version	Recommended Use	Likely User
1. Computerized Versions [2,3]	Suitable for extensive calculations; indispensable for complex highway situations.	Specialists in highway noise control. Certain data processing background required.
2. Original Manual Method [1,4]	Suitable for medium-sized jobs. Can handle all situations.	Highway engineers and specialists in noise control.
3. Simplified Version (This Report)	Planning purposes and preliminary design; useful for simple topography.	All users, particularly environmental planners and non-specialists.

There is one instance, however, where the simplified version departs from the FHWA methodology. It is concerning the function relating the change in ground attentuation with the increase of the receiver (or barrier) height above ground. Briefly, the FHWA model assumes that, as soon as the receiver (or barrier) is 3 m or more above ground, the ground is acoustically hard -- even if it was considered to be acoustically soft for receiver (or barrier) heights just below 3 m. This abrupt change in ground cover, and consequently in sound levels, for receivers close to 3 m in height has been replaced in the simplified model by a more gradual function which takes into account not only the height of the receiver above ground, but also the distance between the noise source and the receiver, and other factors. The procedure is outlined in Section 4.2, Step 3.

2/ SCOPE OF THE SIMPLIFIED METHOD

The FHWA noise prediction method has been simplified to make calculations easier and faster. However, this simplified version may become inaccurate when any or all of the following conditions are encountered:

- There are substantial differences between the speed of cars, medium trucks, and heavy trucks (about 8 to 10 km/h or more).
- The distance between source and receiver is smaller than 15 m.
- The topography of the study area is very irregular (e.g., many different intervening structures, existing and artificial barriers, and different ground cover types are present).
- The roadway has many ramps and curved sections (e.g., near interchanges).

If the above conditions apply, it is recommended to use the original manual method described in Reference 1, or its computerized version called STAMINA, described in References 2 or 3.

In general, the simplification has not reduced the number of variables included in the original method. The following is the list of variables which can be included and accounted for in the simplified method.

A/ total volume of traffic, V, in vehicles per hour (vph)
B/ percentage of cars (and light trucks), P
C/ percentage of medium trucks and buses, Q
D/ percentage of heavy trucks, R
E/ average speed of traffic flow, S, in km/h
F/ distance from source to receiver, D, in metres
G/ ground cover between source and receiver:
   i) hard site (acoustically reflective, e.g. pavement), and
   ii) soft site (acoustically absorptive, e.g., grassland)
H/ intervening structures, such as barrier walls and/or earth berms, depressed/elevated sections, rows of houses and/or buildings, vegetation (i.e., trees or shrubs)
I/ highway gradient
J/ pavement surface texture
K/ traffic flow characteristics (e.g., stop/go).

3/ MATHEMATICAL MODEL

The basic prediction equations were developed for an infinitely long, straight and level highway with a continuous, steady flow of traffic and no intervening structures between the highway and the receiver (assumed to be 1.2 m above ground). Conditions which depart from this ideal model are accounted for as simple decibel adjustments.

Derivation of the basic simplified equations is given in Reference 4. For normal absorptive ground cover between the roadway and the receiver, such as grass and shrubs (characterized as $\alpha = 1/2$ in Ref.1) the basic simplified equation for caculating sound level, L_{eq}, is:

$$L_{eq} = 10 \log [5.32\ V S^2 K\ D^{-1.5}] \qquad (1)$$

where $$K = \frac{PS}{1040} + \frac{Q\sqrt{S}}{9.6} + \frac{23.5R}{\sqrt{S}} \qquad (2)$$

where V = total number of vehicles per hour
S = average speed for all traffic, km/h
D = distance from roadway centreline to receiver, metres
P,Q,R = percentages of cars, medium trucks, and heavy trucks, respectively

The factor K is a summation of relative sound pressure levels of traffic components (P, Q, R).

For reflective ground cover between roadway and receiver, such as paved parking lots and service roads (characterized as $\alpha = 0$ in Reference 1)

Equation 1 becomes:

$$L_{eq} = 10 \log [1.8\ V\ S^2 K\ D^{-1}] \qquad (3)$$

where the symbols are as previously defined.

The above equations assume that the average traffic flow speeds of the three vehicle types (cars, medium trucks, heavy trucks) are similar in magnitude. A rigorous examination of this assumption may suggest difficulties with compliance. However, the speeds of the three vehicle types always exhibit certain variation and their ranges often overlap. Also, the average speeds of the three vehicle types are inevitably correlated. Thus, the use of the overall average traffic flow speed is often a good approximation.

Equations 1 and 3 may also be solved by using the nomograph given in Figure 1.

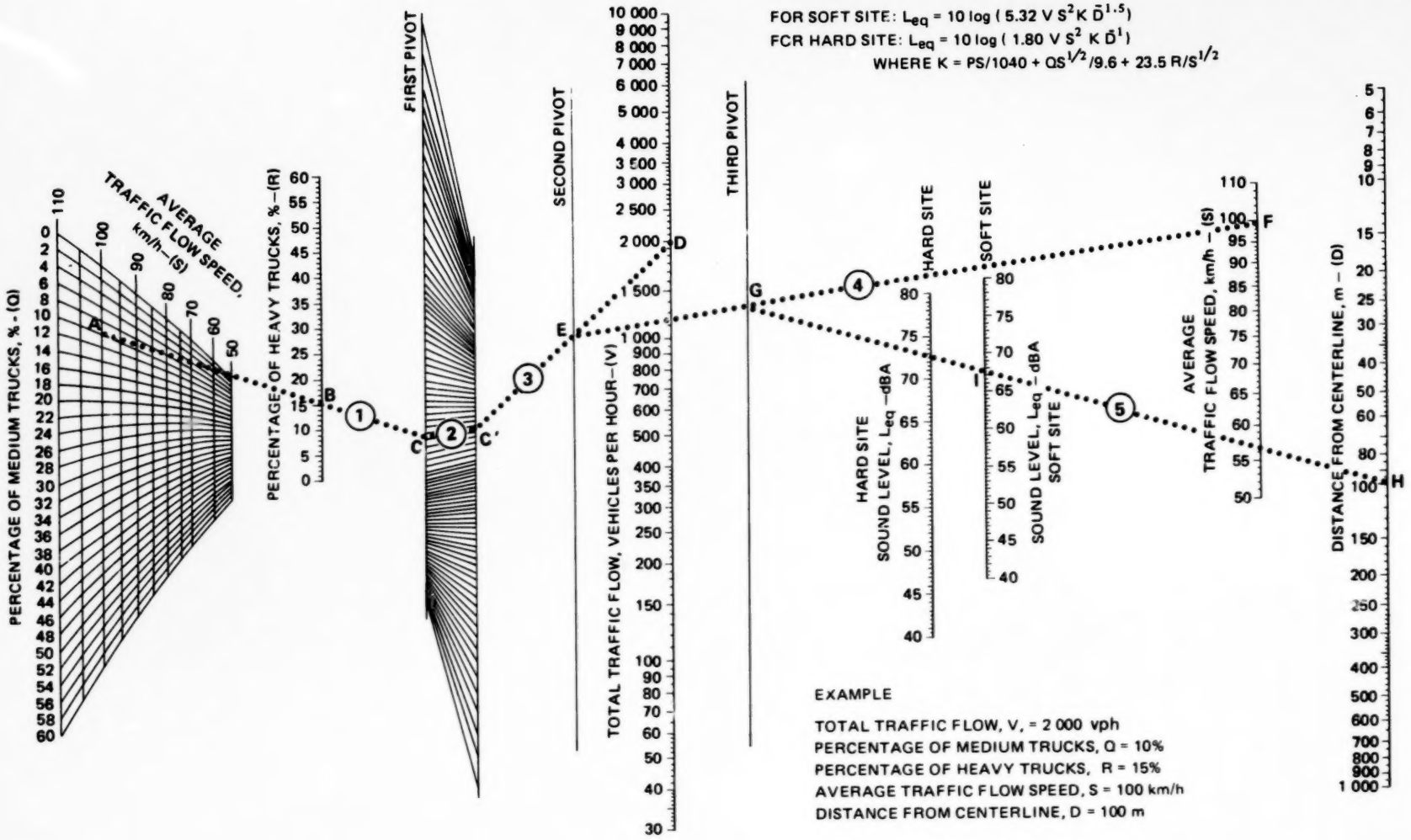
FOR SOFT SITE: $L_{eq} = 10 \log (5.32 \, V \, S^2 K \, D^{1.5})$
FOR HARD SITE: $L_{eq} = 10 \log (1.80 \, V \, S^2 \, K \, D^1)$
WHERE $K = PS/1040 + QS^{1/2}/9.6 + 23.5 \, R/S^{1/2}$
PERCENTAGE OF MEDIUM TRUCKS, % - (Q)
AVERAGE TRAFFIC FLOW SPEED, km/h – (S)
PERCENTAGE OF HEAVY TRUCKS, % – (R)
FIRST PIVOT
SECOND PIVOT
THIRD PIVOT
TOTAL TRAFFIC FLOW, VEHICLES PER HOUR – (V)
HARD SITE SOUND LEVEL, L_{eq} – dBA
SOFT SITE SOUND LEVEL, L_{eq} – dBA
AVERAGE TRAFFIC FLOW SPEED, km/h – (S)
DISTANCE FROM CENTERLINE, m – (D)
A
B
C
C'
D
E
F
G
H
I
1
2
3
4
5
EXAMPLE
TOTAL TRAFFIC FLOW, V, = 2 000 vph
PERCENTAGE OF MEDIUM TRUCKS, Q = 10%
PERCENTAGE OF HEAVY TRUCKS, R = 15%
AVERAGE TRAFFIC FLOW SPEED, S = 100 km/h
DISTANCE FROM CENTERLINE, D = 100 m
RESULTS: L_{eq} – SOFT SITE = 67.5
L_{eq} – HARD SITE = 72.5

Figure 1/ Nomograph for Predicting L_{eq} Sound Levels

4/ CALCULATING PROCEDURE

4.1/ Simple Situations

In simple situations where:

i/ the variables A to G as listed in Section 2 are reasonably constant for a roadway section of approximately 6 to 8 D (where D is the distance from the roadway centreline to the receiver); and

ii/ the variables H to K are not pertinent,

only the nomograph in Figure 1 (or Equations 1 to 3) need be used for calculating sound levels, L_{eq}.

Example

Calculate L_{eq} for the following situation:

- the plan view and cross-section are as shown in Figure 2
- 2000 vph in both directions, i.e., total traffic for all lanes
- average speed 100 km/h
- 10% medium trucks
- 15% heavy trucks
- 8 lanes of traffic
- grade < 2%

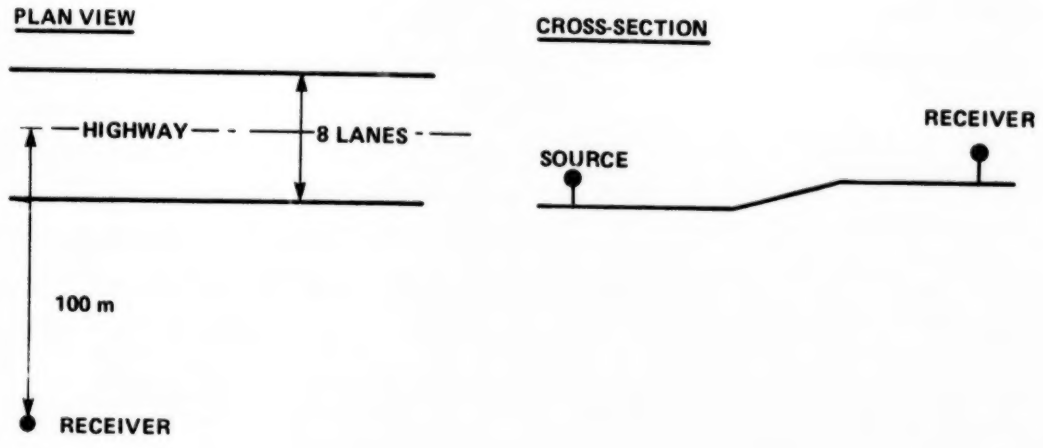

Figure 2/ Physical Layout of Example Situation

- normal road surface, normal absorptive ground cover
- distance from receiver to roadway centreline is 100 m, and the receiver is 1.2 m above ground
- there is a clear line-of-sight to the roadway for about 800 m

Solution

This is a simple case as defined above and can be solved using the nomograph only. The following step-by-step solution is based on the nomograph in Figure 1.

i/ Locate point A on the left-hand side of the nomograph where lines for 100 km/h and 10% medium trucks intersect.

ii/ Enter the percentage of heavy trucks (15%) at point B. Join points A and B with a straight line and extend it until it intercepts the first pivot line at point C.

iii/ Follow the direction of tracing lines to the right of Point C, to establish point C'.

iv/ Enter the total traffic flow (2000) at point D. Join points C' and D with a straight line which intercepts the second pivot line at point E.

v/ Enter traffic flow speed (100 km/h) at point F. Join points E and F with a straight line which intercepts the third pivot line G.

vi/ Enter the distance (100 m) from the centreline on the right-hand side of the nomograph at point H. Join this point with the point G on the third pivot line using a straight line. This line intercepts the L_{eq} sound level line, soft site, at point I, which is the L_{eq} sound level = 67.5 dBA.

4.2/ Situations Involving Sections of Roadways and Intervening Structures (Barriers)

Other, more complex situations, may require a division of the roadway into sections (e.g., some highway sections may be shielded by a barrier and some may not) or inclusion of more than one roadway (e.g., near an intersection). In these cases, the general calculation procedure is:

i/ to identify required highway sections and roadways,
ii/ to calculate the sound level contribution from each section or roadway, and
iii/ to sum all contributions logarithmically.

The procedure is described below using a step-by-step approach. Calculation can also be organized by using Table 1.

Step 1

Divide the highway into straight sections to approximate the actual highway alignment. Wide highways (e.g., multi-lane highways with median) may be considered as two roadways which are then divided into sections. For the approximation of the highway by sections, it is often advantageous to apply the concept of equivalent distance described in Step 4, ii.

Sections should be as long as possible but short enough to ensure that the following variables are approximately constant on the length of the section:

- traffic flow characteristics (volume, composition, speed);
- break in the line-of-sight between the highway noise source and the observer's position;
- pavement surface type;
- highway gradient if heavy trucks are present; and
- ground attenuation.

Table 1/ Worksheet for Detailed Calculation

Project Name Date	HIGHWAY SECTION NUMBER					
	1	2	3	4	5	6
1. Total traffic volume, vph						
2. Percentage of medium trucks, Q						
3. Percentage of heavy trucks, R						
4. Average traffic speed, km/h						
5. Perpendicular distance, m						
6. Ground attenuation type (soft, hard)						
7. Basic sound level **Figure 1**						
8. Adjustment for highway gradient, only positive **Table 2**						
9. Adjustment for ground attenuation only positive **Table 3**						
10. Adjustment for element size, only negative **Table 4**						
11. Barrier adjustment, only negative **Step 4**						
12. Adjustment for pavement surface, positive or negative **Table 6**						
13. Adjustment for houses and vegetation, only negative **Step 6**						
14. Arithmetically add results in rows 7 to 13						
15. Logarithmically add contributions from all highway sections **Table 7**						

Step 2

Using the nomograph of Figure 1 (or the equations), calculate the sound levels emitted by each road section for a given location. Use perpendicular distance, D, as defined in Figure 4.

Adjustment for highway gradient (within Step 2, if necessary).

- Adjustment for highway gradient is applied only to heavy trucks travelling in the up-gradient direction only. (There is no adjustment for cars, medium trucks, or for heavy trucks in downhill grade.)

- Total vertical distance from the bottom of the grade to the top should be at least 6 to 7 m.

The positive adjustments for highway gradient are presented in Table 2. It may be noted that the adjustments in Table 2 are in a form of multiplication factors rather than in the form of dB adjustments used in Reference 1. Both forms yield identical results.

Table 2/ Adjustment for Percentage of Heavy Trucks (R) on Grades

Gradient, %	Multiply R by a Factor of:
<2	1
3 to 4	1.5
5 to 6	2
>7	3

Step 3

Calculate adjustment for ground attenuation. (This adjustment is applied only to a soft site.)

Note: This step includes the only departure of the simplified method from the FHWA model [1] by assuming that ground attenuation depends not only on the type of ground cover and the height of the receiver (or barrier) above ground, but also on:
a) a horizontal distance between the source and the receiver, and
b) a combined height of the source receiver and barrier above ground.

The later is acheived by introducing the concept of total effective height.

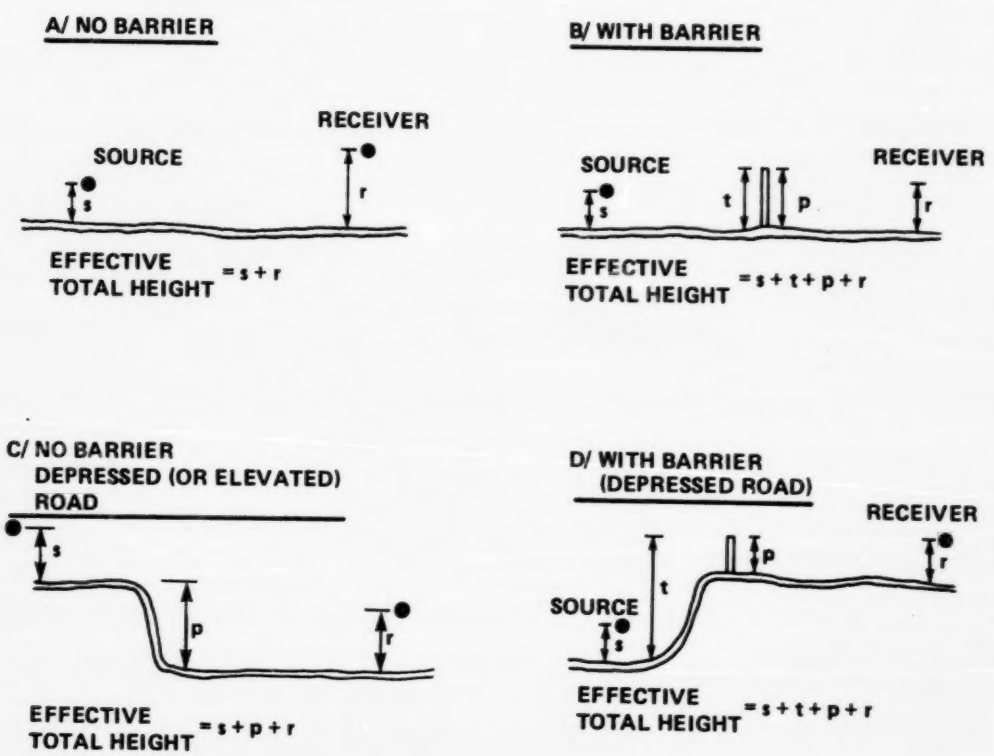

Figure 3/ Effective Total Height Above Ground

The procedure is as follows:

i/ Calculate the effective total height above ground using Figure 3.

ii/ Use Table 3 to obtain an adjustment for ground attenuation. This is a positive adjustment which will increase sound levels obtained in Step 2.

Table 3/ Adjustment for Ground Attenuation (Soft Site Only)

Effective Total Height Above Ground, m	Horizontal Distance from Source to Receiver, m							
	20	30	40	50	100	200	300	>400
up to 3.5	0	0	0	0	0	0	0	0
3.5 to 5.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5.1 to 6.5	0.5	0.7	1.0	1.0	1.0	1.0	1.0	1.0
6.6 to 9.0	0.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
9.1 to 11.0	0.5	1.5	1.7	2.0	2.0	2.0	2.0	2.0
11.1 to 14.0	0.5	1.5	2.0	2.5	2.5	2.5	2.5	2.5
14.1 to 17.0	0.5	1.5	2.0	2.5	3.0	3.0	3.0	3.0
17.1 to 22.0	0.5	1.5	2.0	2.5	3.5	3.5	3.5	3.5
22.1 to 27.0	0.5	1.5	2.0	2.5	4.0	4.0	4.0	4.0
27.1 to 32.0	0.5	1.5	2.0	2.5	4.0	4.5	4.5	4.5
32.1 to 39.0	0.5	1.5	2.0	2.5	4.0	5.0	5.0	5.0
39.1 to 46.0	0.5	1.5	2.0	2.5	4.0	5.5	5.5	5.5
46.1 to 54.0	0.5	1.5	2.0	2.5	4.0	5.5	6.0	6.0
54.1 to 64.0	0.5	1.5	2.0	2.5	4.0	5.5	6.5	6.5

The new procedure, largely based on a model developed by the Canadian NRC [5], eliminates certain inconsistencies in the treatment of ground attenuation by the FHWA model for receiver (or barriers) close to 3 m in height and for situations where both the source and the receiver, as well as the barrier, are located several metres above ground. For example, the FHWA model considers the ground to be sound reflecting, regardless of the actual ground condition and the propagation distance, for all situations involving propagation over a top of a barrier 3 m or more in height. In the new procedure, as the total effective height of sound propagative is increased, or the propagation distance is increased, the effect of extra ground attenuation is gradually lost.

Step 4

Calculate adjustment for element size.

The adjustment for element size is based on the subtended angle between the receiver and the highway section end points (refer to Figure 4). Adjustment for element size for various subtended angles can be obtained from Table 4.

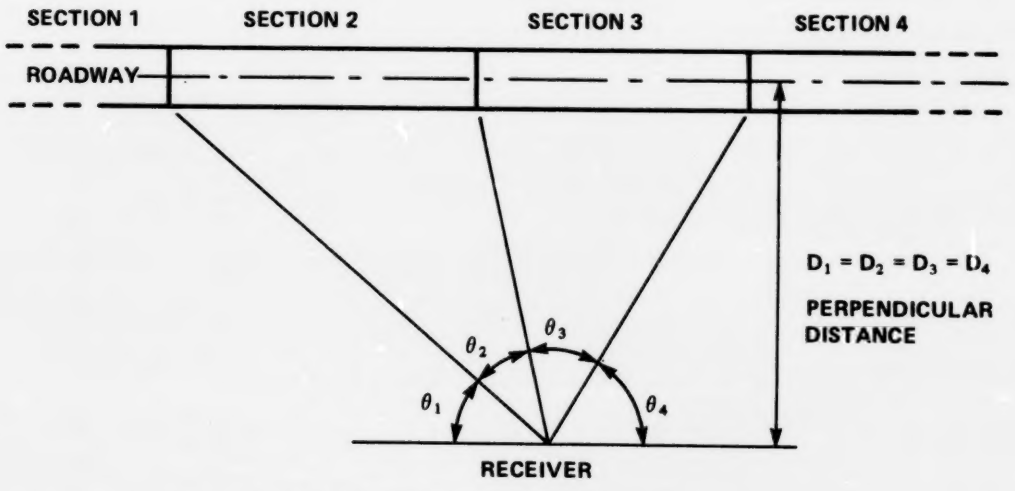

Figure 4/ Adjustment for Element Size

Table 4/ Adjustment for Element Size

Adjustment (dBA)					
Angle Subtended θ_i Degrees	Hard Site	Soft Site	Angle Subtended θ_i Degrees	Hard Site	Soft Site
180	0	0	50	-5.6	-4.6
160	-0.5	-0.2	45	-6.0	-5.0
140	-1.1	-0.5	40	-6.5	-5.5
120	-1.8	-1.0	35	-7.1	-6.1
100	-2.6	-1.7	30	-7.8	-6.8
90	-3.0	-2.1	25	-8.6	-7.6
80	-3.5	-2.5	20	-9.5	-8.5
70	-4.1	-3.1	15	-10.8	-9.8
60	-4.8	-3.8	10	-12.6	-11.6
55	-5.1	-4.1	5	-15.6	-14.6

The adjustments have been calculated as average values based on the methodology presented in Reference 1.

Step 5

Adjustment for the shielding effect of natural or artificial barriers is done as follows:

i/ Determine the effective height of the source from Table 5, which is based on the equation:

$$\bar{h}_s = \sqrt[4]{R}$$

where: R = percentage of heavy trucks

h_s = effective height of source, in metres.

Table 5/ Effective Source Height

Percentage of Heavy Trucks in Total Flow	Effective Height of Source
1% (or less)	1.0 m
2%	1.2 m
3%	1.3 m
5%	1.5 m
7%	1.6 m
10%	1.8 m
15%	2.0 m
20%	2.1 m
30% (or more)	2.4 m

11/ Determine the location of the noise source. The noise source may be assumed to be located over the geometric mean of the distances from the observation point, to:

(a) the nearest (D_N) traffic lane, and to

(b) the farthest (D_F) traffic lane.

$$D_E = \sqrt{D_N \cdot D_F}$$

where: D_E= equivalent distance.

As an example, consider the situation shown in Figure 5 and described below:

Assume 3.75 m lanes, D = 100 m

D_N = 100 - 7.5 - (3.5 x 3.75) = 79.4 m

D_F = 100 + 7.5 + (3.5 x 3.75) = 120.6 m

$D_E = \sqrt{79.4 \times 120.6}$ = 97.8 m

Note: To increase accuracy, equivalent distance can be also used instead of "distance", in Equations 1 and 3 and in the nomograph of Figure 1.

iii/ Prepare a cross-sectional drawing of the highway and the receiver and draw a line representing the direct line-of-sight between the source and the receiver. The height of the receiver is assumed to be 1.2 m above the ground, unless second storey windows are being considered.

iv/ Determine barrier diffraction loss from a barrier nomograph in Figure A2. Refer to the Appendix for details on how to use the barrier nomograph.

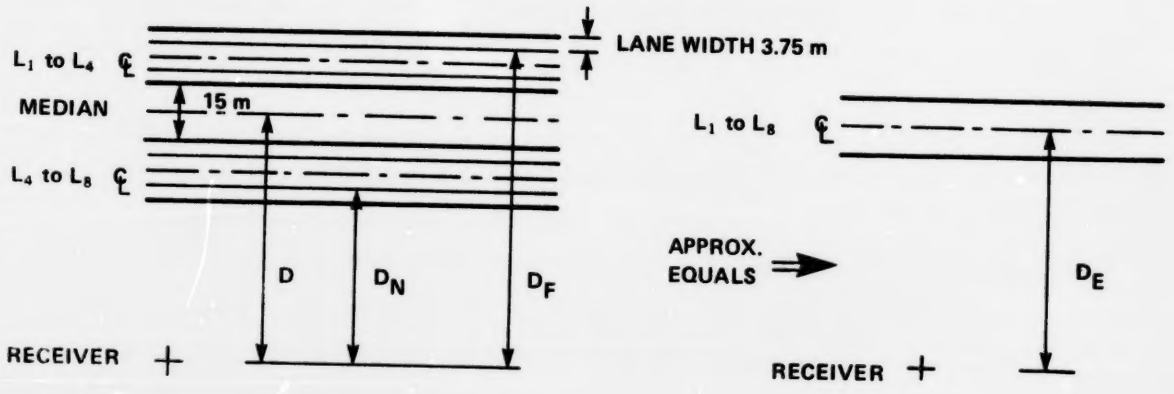

Figure 5/ Equivalent Distance

Step 6

Adjustment for pavement surface type is made as follows:

Use Table 6 to obtain adjustment for surface type. The adjustments apply to sound levels emitted by the total traffic flow and are, therefore, applied to the sound level, L_{eq}.

Table 6/ Adjustment for Pavement Surface Type

Pavement Surface Type	Adjustment, dBA
Typical asphalt pavement such as HL-1	0
Open-graded friction course	-2.5
Dense-graded friction course	-1.5
Smooth concrete pavement	-1
New concrete pavement, wire brush finish	+6
Grooved concrete pavement	+6 to +8

Step 7

The adjustment procedure for shielding due to vegetation is as follows:

- If tree spacing is dense so that no visual path between the source and receiver exists (does not hold for deciduous areas in winter), and if the trees are at least 5 m above the line-of-sight, apply a 5 dBA reduction per 30 m of depth, up to a maximum of 10 dBA.

- If the tree spacing is not as dense as above, and if the trees protrude above a barrier or berm, recognize that a small but unknown reduction may occur in the attenuation otherwise provided by the barrier or berm.

- If the above conditions do not apply, assume no effect due to vegetation.

Step 8

Adjustment for shielding effect of houses:

Subtract 3 dBA for the first row of houses when the buildings occupy 49% to 65% of the length of the row. Subtract 5 dBA when the buildings occupy 65% to 90% of the length of the row. No attenuation is allowed for rows of houses that occupy less than about 40% of the length of the row. Additional attenuation of 1.5 dBA is provided by each successive row until a total attenuation of 10 dBA for all rows is obtained. This is the maximum attenuation that this mechanism provides.

Note: The excess attenuation provided by ground effects is assumed to end when the sound waves reach the dense woods or the first row of buildings. Thus, the attenuation provided by dense woods and rows of buildings is only additive to the attenuation provided by geometric spreading (3 dBA per distance doubling). In addition, the combined effects of dense woods and rows of buildings are only additive until a maximum of 10 dBA attenuation is achieved. Thereafter the effects of additional woods and rows of buildings are ignored [1].

Step 9

Adjustment for the effect of interrupted flow.

Latest data indicate that this adjustment is not necessary. For intersections, traffic volumes on all intersection branches, and the corresponding average operating speeds during the green cycle, should be used to calculate sound levels.

Step 10

After the preceding adjustments (Steps 3 to 9) are calculated for each highway section (if applicable), they are arithmetically added (or subtracted) from the basic sound level obtained in Step 2 (Table 1 can be used to organize the calculations).

Step 11

The adjusted sound levels for each highway section are added logarithmically to obtain overall sound level. Refer to Table 7 for decibel addition.

Table 7/ Addition of Sound Levels Expressed in dB

If higher level exceeds lower level by:	Additions to lower level
0 to 0.5 dB	3.0 db
0.6 to 1.5 dB	2.5
1.6 to 3.0 dB	2.0
3.1 to 4.5 dB	1.5
4.6 to 7.0 dB	1.0
7.1 to 12 dB	0.5
more than 13 dB	0

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[5] Halliwell, R.E. and Quirt, J.D., "Traffic Noise Prediction," Building Research Note 146, National Research Council of Canada, Division of Building Research, Ottawa, 1979.

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APPENDIX A/ Barrier Nomograph Procedure

The nomograph used to determine the attenuation of a proposed barrier design was developed on the assumption of an infinitely straight roadway with a barrier of uniform height that parallels the roadway at a constant offset. This condition rarely prevails, and while the preceding assumption should be noted, it need not be stringently interpreted.

Prior to the use of the nomograph, various physical parameters must be determined. From the cross-section drawings (e.g. Fig. A1) the following can be determined:

- Line-of-Sight Distance (L/S), the slant distance (not the horizontal distance) from the source to the receiver.

- Barrier Break, the distance along a perpendicular line from the line-of-sight to the top of the barrier. This distance is also referred to as the "effective height" of the barrier.

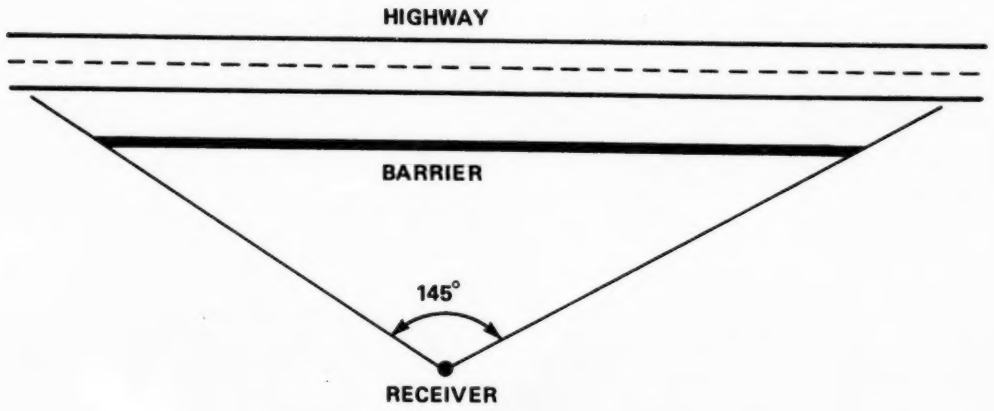
- Barrier Position, the slant distance along the L/S from the barrier break point to either the source or the observer (whichever is the shorter distance).

When using cross-sectional drawings to obtain the preceding parameters, the vertical and horizontal scales should be identical. From the plan view drawings, the following parameter can be determined:

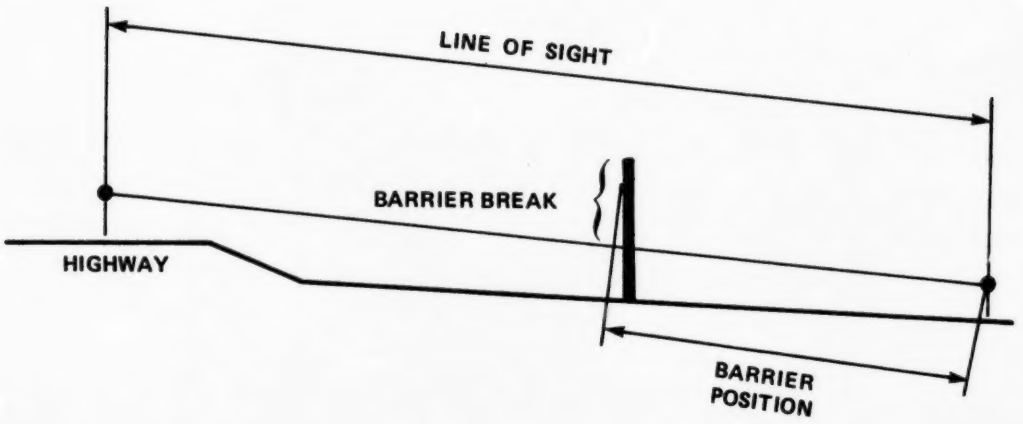
- Subtended Angle, the angle subtended at the receiver by the ends of the barrier. The position of the receiver may be centred on the barrier, off-centre, at the end of the barrier, or beyond the end of the barrier.

The following example will illustrate the use of the nomograph procedure in determining the attenuation of a barrier.

PLAN VIEW



CROSS SECTION



GIVEN :

- EIGHT (8) 3.75 m LANES EACH DIRECTION
- 15% OF HEAVY TRUCKS, APPARENT HEIGHT OF SOURCE 2.0 m
- 4.5 m BARRIER
- HEIGHT OF RECEIVER 1.2 m

Figure A1/ Barrier Situation

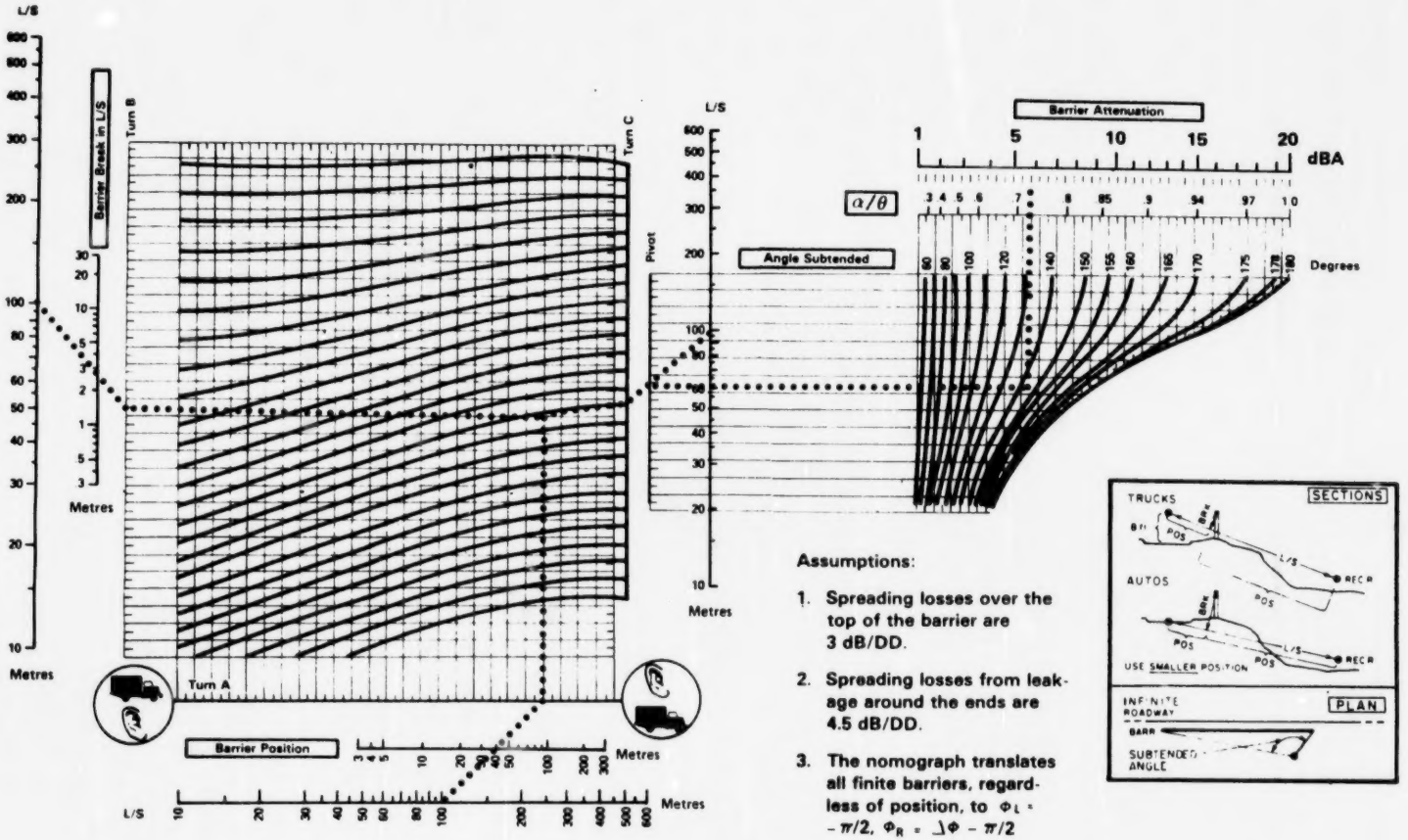


Figure A2/ Barrier Nomograph

Example

Given Data:

- eight 3.75 m lanes in each direction, see Figure A1
- 15% of heavy trucks,
- apparent height of source, 2.0 m
- 4.5 m barrier
- height of receiver, 1.2 m

Determination of Parameters:

- Line-of-sight L/S = 100.0 m
- Barrier Break = 2.8 m
- Barrier Position = 40.0 m
- Subtended Angle = 145°

These parameters are used in the following manner to determine the barrier attenuation. (Refer to the barrier nomograph, Figure A2.)

Starting at the bottom, a line is drawn from the L/S length, through the barrier position, to turning line A. After turning upward, this line sets the position of the barrier relative to the source and receiver. Then, starting at the left, a line is drawn from the L/S length through the barrier break-in-L/S line to turning line B, and then horizontally into the attenuation curves. The intersection of these two lines will lie on some particular barrier attenuation curve. This curve is followed upward to the right, to turning line C, then turned to the L/S length. From where this line crosses the pivot line, a line is drawn horizontally to the right and reflected vertically upwards from the proper subtended angle line, to the barrier attenuation line.

Using the barrier nomograph (Figure A2), the following attenuation is determined:

- Attenuation due to Diffraction = 6.0 dBA

These barrier diffraction attenuations are then deducted from the "no barrier" sound levels produced by a given highway section or entered in Table 1.

Points to Remember When Using the Nomograph

a/ The vertical and horizontal scales on the cross-section drawings should be equal.

b/ On a multi-lane roadway, where traffic volumes have been concentrated into a reduced number of lanes, the noise source on the cross-section drawings should be placed at the equivalent distance from the receiver (refer to Step 4, ii).

c/ Always use the simplest line-of-sight (L/S), from the receiver perpendicular to the roadway. The L/S is the slant distance not the horizontal distance.

d/ The barrier break is measured perpendicular to the L/S.

e/ The barrier position is the slant distance for the barrier to the source, or the slant distance from the barrier to the receiver. The distance used in the nomograph is the smaller of these two distances.

f/ If the receiver is just at the end of the barrier, the largest subtended angle possible is 90°, which results in a maximum attenuation of 3 dBA. For receivers beyond the end of the barrier the nomograph becomes inaccurate and should not be used.

g/ If two or more barriers break the line-of-sight, only the attenuation of the most effective barrier should be used.

h/ Holes, openings, or breaks in the continuity of the barrier cause a pressure doubling effect which tends to amplify the noise. Any discontinuity in the barrier should be avoided if possible.

Other Considerations, Transmission Loss (TL)

The transmission loss of a barrier is its resistance to the transmission of sound energy through the barrier. Therefore, a high TL means less

sound energy gets through the barrier. The transmission loss is dependent upon:

- wall weight (surface density, seldom exceeds 20 kg/m^2)
- wall stiffness
- angle of incidence of approaching noise
- frequency of noise

Low transmission losses of barrier materials (20 dBA and lower) can detract noticeably from barrier attenuation.

Further details concerning transmission loss can be obtained from Reference 6 which presents a method for calculating the overall effect of sound transmission losses on barrier performance.

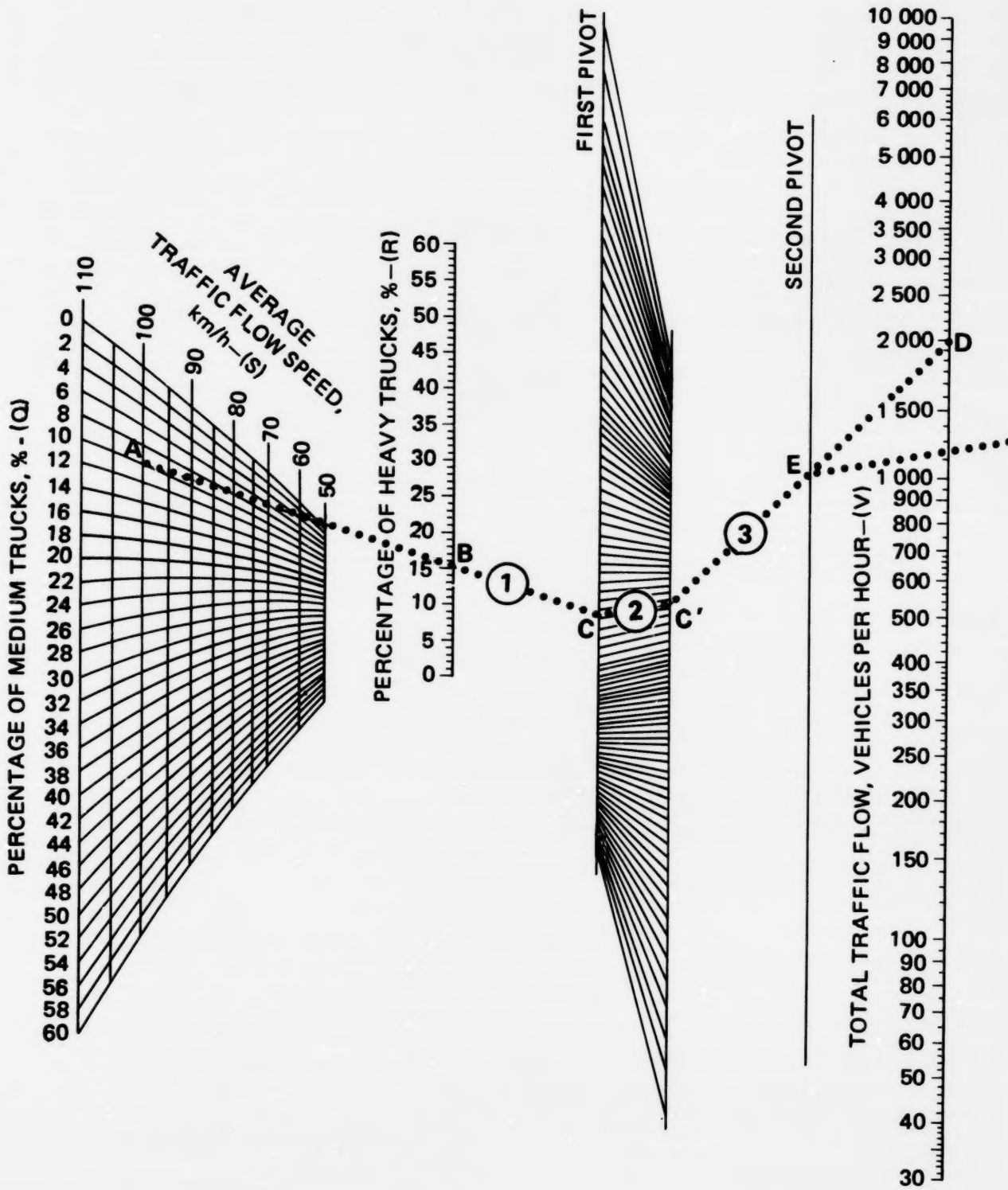
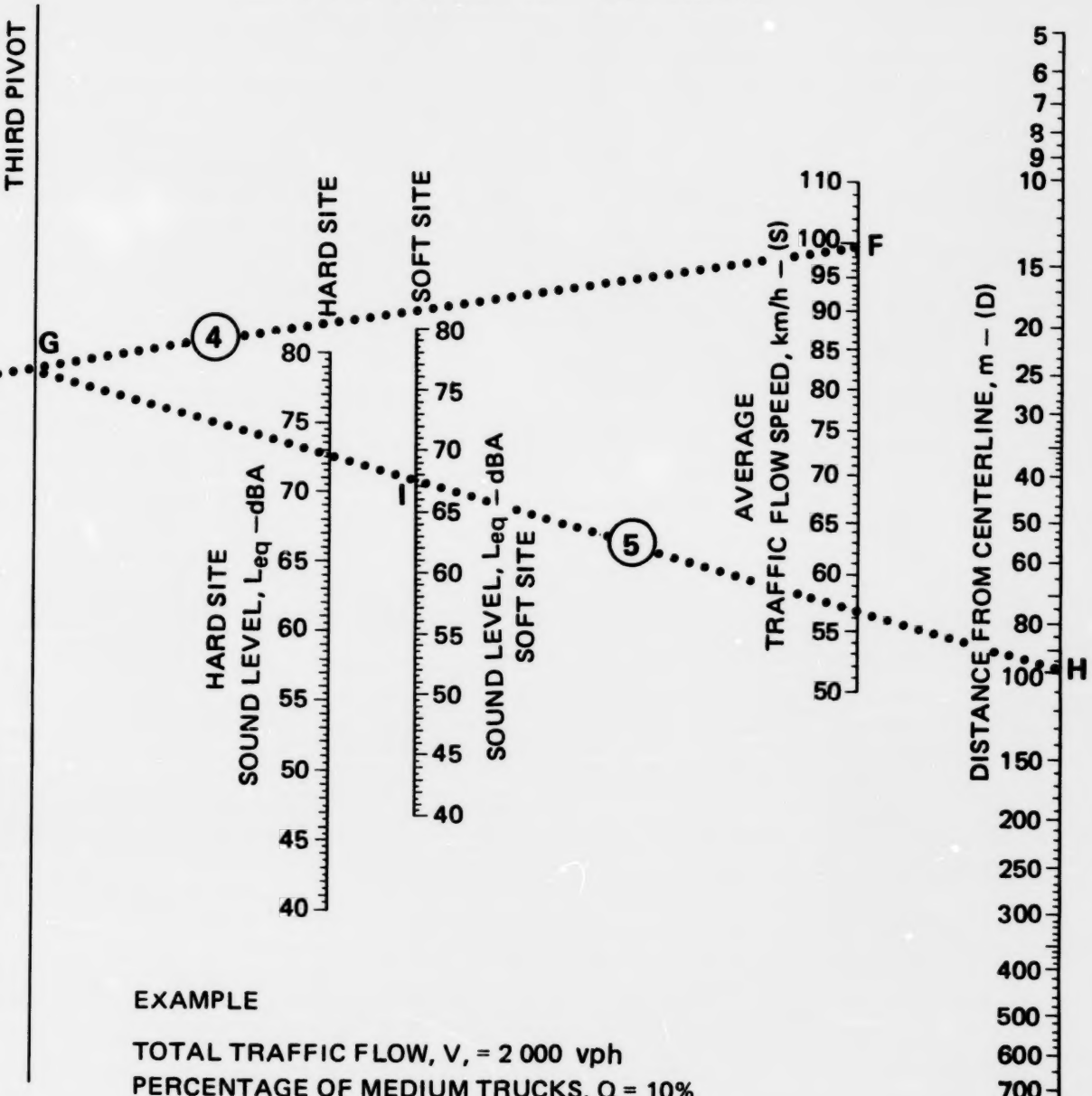


Figure 1/ Nomograph for Predicting L_{eq} Sound Levels

FOR SOFT SITE: $L_{eq} = 10 \log (5.32 \, V \, S^2 K \, \bar{D}^{1.5})$

FOR HARD SITE: $L_{eq} = 10 \log (1.80 \, V \, S^2 \, K \, \bar{D}^{1})$

WHERE $K = PS/1040 + QS^{1/2}/9.6 + 23.5 \, R/S^{1/2}$


THIRD PIVOT
G
4
HARD SITE
SOFT SITE
I
5
F
H
HARD SITE SOUND LEVEL, L_{eq} – dBA
SOFT SITE SOUND LEVEL, L_{eq} – dBA
AVERAGE TRAFFIC FLOW SPEED, km/h – (S)
DISTANCE FROM CENTERLINE, m – (D)
80 75 70 65 60 55 50 45 40
80 75 70 65 60 55 50 45 40
110 100 95 90 85 80 75 70 65 60 55 50
5 6 7 8 9 10 15 20 25 30 40 50 60 80 100 150 200 250 300 400 500 600 700 800 900 1 000

EXAMPLE

TOTAL TRAFFIC FLOW, V, = 2 000 vph
PERCENTAGE OF MEDIUM TRUCKS, Q = 10%
PERCENTAGE OF HEAVY TRUCKS, R = 15%
AVERAGE TRAFFIC FLOW SPEED, S = 100 km/h
DISTANCE FROM CENTERLINE, D = 100 m

RESULTS: L_{eq}– SOFT SITE = 67.5
L_{eq}– HARD SITE = 72.5